



Galileo is a navigation system that aims to improve on existing positioning devices, but what is its true potential for putting people in their place? According to Mike Bedford, the sky's the limit

It's not every day someone puts \$5.2 billion (around £2.8 billion) worth of high-tech equipment at your disposal. This is exactly what happened when the US government made its global positioning system (GPS) available for civilian use. Using this satellite navigation system via a £100 handheld GPS receiver, you can find out where you are, to within a few metres, anywhere on the face of the Earth. A couple of hundred pounds buys a system that gives you turn-by-turn instructions on the road, in the form of a GPS add-on and software for a handheld PC. But impressive as it sounds, GPS is yesterday's technology. Its successor, Galileo, the result of a partnership between the European Space Agency and the European Union (EU), will go live in 2008.

FLIGHT OF THE NAVIGATOR

If you've just bought one of the latest GPS receivers you'd be forgiven for asking why we need Galileo. What is wrong with GPS, and how can Galileo improve on it? To find out, we spoke to Jean-François Bou, Galileo project director for Thales Navigation. Thales is a key player in Galileo Industries, a joint venture of leading European space companies that was formed to develop the Galileo infrastructure.

We asked what extra features the new system would offer. Bou explained how the existing GPS transmits two signals: an open signal that is free to all, and a military one that can be used only by the US and allied military forces. "The problem with the open system is that it's under the control of the US Department of Defense, who can close the tap when they want for security purposes," he said. While this may sound like scaremongering, the US government has a history of degrading the open signal for security reasons.

Until 2000, a feature called selective availability was used to degrade the open signal deliberately, thus reducing accuracy to a few tens of metres. The Presidential statement announcing the end of selective availability suggested an alternative means of control: "We have demonstrated the capability to selectively deny GPS signals on a regional basis when national security is threatened."

Although plans for Galileo include security measures to prevent it being used in a way that would compromise European security, the EU makes a lot of the fact that the European system will be managed in Europe and won't be under the control of the military. There are certainly practical reasons for building a European alternative, but the EU rhetoric suggests a degree of flag-waving: "The

European Union cannot afford not to become involved in what will be one of the main sectors of industry in the 21st century. That would mean becoming dependent on systems and technologies developed outside Europe for applications vital to the running of the society of tomorrow."

COMPLEMENTARY SERVICE

Bou described how Galileo and GPS could provide backup services for each other, a concept known as redundancy. "If there's a gap in GPS, Galileo will take over," he explained. "This is one of the big merits. GPS and Galileo are complementary, not competing." As well as providing location information, navigation satellites provide super-accurate timing information. "The synchronisation of power grids relies on GPS, and mobile phone networks are also synchronised by GPS clocks. This is why redundancy is so important," said Bou.

But Galileo is more than just a service that fills in the gaps when a GPS satellite fails. Bou explained that while the GPS satellites transmit just two types of signals – military and open – Galileo transmits 10 separate navigation signals, resulting in five distinct services tailored to the requirements of different types of users. Just like GPS, there will be an open signal that's freely available, but this is just the start. The other signals provide a commercial service, a safety of life service, a public regulated service and a search and rescue service.

Bou went on to explain how the safety of life service provides system status information. "This way, users can be told whether or not to rely on the



GPS devices are popular for helping drivers identify and plan a route; could Galileo improve matters?

location, depending on system status.” Another useful service is the one intended for search and rescue, which has a return link. When a distress message is triggered, the user will receive an acknowledgement that his location has been received by the emergency services. The user then has the option of transmitting additional information on the nature of the problem.

Other advanced features are on the cards, although the final decision on what is provided has still to be made. Users of certain subscription services may receive a service-level contract that guarantees a level of availability; other services might include a means of authenticating the signal. This is similar to the digital signatures that are used to provide legal proof that a certain person sent an email. When applied to Galileo, authentication will provide a guarantee that the received signal has not been altered. This could be used for commercial applications that require a proof of location.

CLEAR SIGNALS

Many wonder how accurate Galileo will be in comparison with other kinds of GPS. According to Bou, “The open service is slightly [more accurate], but GPS is undergoing improvements and, in time, the two will be equivalent.”

However, Bou added, “Accuracy is only one aspect, and most users aren’t looking for more than GPS’s seven-metre accuracy. When you’re walking down a street or controlling a fleet of vehicles, you don’t care whether the accuracy is seven metres or 17 metres. Availability is far more important. In city centres it’s easy to lose the signals”.

Bou explained that because the satellite signals cannot pass through concrete and brick, GPS is available in just 50 per cent of urban areas. Galileo will improve on this because of the slightly different orbits. The main benefits, however, will come from dual-mode receivers that are capable of receiving and processing both GPS and Galileo signals. Instead of the 24 satellites of GPS there will be 61 satellites available, which will increase availability in urban areas to 90 per cent.

STATS AMAZING

According to the EU, the economic importance of Galileo is huge. The system will cost \$3.2 billion (around £2.2 billion), but it is estimated that it will generate 4.6 times that amount and create 100,000 jobs. If you can find your way around in the car without satellite technology, these figures may seem optimistic. Does the world need more than the 60 million GPS receivers already in use? According to Bou, the answer is a resounding yes. He said, “Soon billions of GPS receivers will be in use worldwide, since chipsets will be included in every mobile phone.” So perhaps one day soon, we will all have satellite navigation technology in our pockets. 

DIAGRAMS: MIKE HARDING

HOW IT WORKS

Satellite navigation

Galileo will work like any GPS. The system will have a constellation of 27 satellites (compared to 24 for the existing GPS) and will operate at an altitude of 23,600km above the Earth’s surface. Because there are so many satellites, there’s a good chance at least four will be visible from most places on the Earth’s surface, even if much of the sky is obscured by tall buildings or trees. To grasp the significance of the magic figure of four, we must consider one satellite and work our way up.

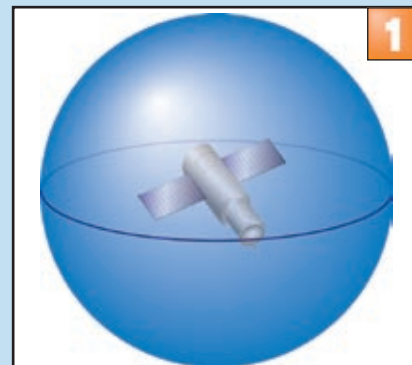
A GPS receiver works by measuring how long a radio signal takes to arrive from a satellite. By multiplying that time by the speed of the radio signal – the same as the speed of light, about 300,000 kilometres per second – it can work out how far it is from the satellite. But if you’re told you are 24,000km from a satellite, for example, all you know is that you’re somewhere on the perimeter of a sphere, with a radius of 24,000km, centred on that satellite. We need additional information to gauge an exact location.

Measuring the time a signal takes to arrive from a second satellite places the receiver on another sphere, perhaps with a radius of 25,000km this time. These two spheres will overlap. The intersection of their surfaces takes the shape of a circle. The two satellite readings will narrow your position down to a point on the edge of this circle.

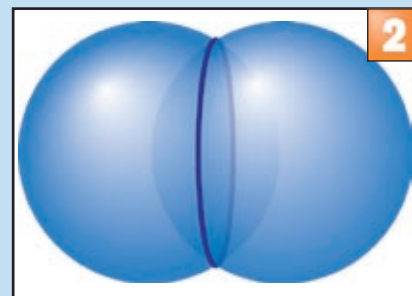
This is a big improvement, but still not definitive. A third satellite is used to define our position on the perimeter of a third sphere. The surfaces of these three spheres intersect at just two points. One is an impossible position way out in space, but the other corresponds to the actual location of the GPS receiver on the Earth’s surface.

However, very accurate clocks are needed on the satellite and the receiver to measure the time taken for the signal to reach the GPS receiver from a satellite. At the speed of light, an inaccuracy of just a thousandth of a second would cause the calculated position to be out by 300km. Highly accurate atomic clocks are used on the satellites, but the GPS receiver has to use a much cheaper clock to keep the price down. Sadly, the simpler clock used in the GPS receiver isn’t as accurate as an atomic clock. Unless the errors are corrected, the calculated location could be way out.

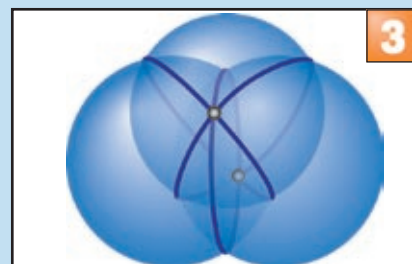
The answer is to use a signal from a fourth satellite to place the GPS receiver on the perimeter of a fourth sphere. Because of the timing error, the perimeter of this fourth sphere won’t pass through the location calculated from the first three satellites. But by using simple algebra, the GPS receiver can work out how much the timings need to be amended for all four spheres to pass through a single point. The end result is a location that is as accurate as if the GPS receiver had been fitted with an atomic clock.



1 A signal from one satellite gives a location anywhere on the perimeter of a sphere



2 Using two satellites, we have two spheres with a circle at their intersection



3 Using a third satellite, three spheres intersect at two points; one is an impossible position but the other marks the location of the receiver

Another problem concerns the positions of the satellites. We assume the GPS receiver knows exactly where each satellite is, but this isn’t straightforward when they are orbiting the Earth at thousands of kilometres per hour. The movement of the satellites is governed by the laws of gravity; their position at any time can be calculated from orbital data. However, other forces such as the gravitational pull of the moon cause disturbances to a satellite’s orbit. This discrepancy from the ideal orbit causes errors in the position calculated by the GPS receiver. To overcome this, the satellites are monitored regularly. Information on how actual orbit differs from theoretical orbit is transmitted to each satellite, then forwarded to the GPS receiver. The receiver uses this data when working out the satellite’s position in orbit and can calculate the position on the Earth’s surface to within about seven metres.